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Changes in Reward after Gastric Bypass: the Advantages and Disadvantages

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Abstract Gastric bypass surgery is an effective long-term weight loss intervention. Key to its success appears a putative shift in food preference away from high-energy-density foods associated with a reduced appetitive drive and loss of neural reactivity in the reward system of the brain towards food. Post-prandial exaggerated satiety gut hormone responses have been implicated as mediators. Whilst the positive impact of bariatric surgery on both physical and psychological outcomes for many patients is clearly evident, a subset of patients appear to be detrimentally affected by this loss of reward from food and by a lack of alternative strategies for regulating affect after surgery. Mindfulness training has emerged as a potential tool in reducing the need for immediate reward that underpins much of eating behaviour. Further research is needed to help identify patients who may be more vulnerable after gastric bypass and which forms of support may be most beneficial.

Keywords Gastric bypass surgery · Bariatric surgery · Food reward · Hedonic · Food addiction · Binge eating disorder · Emotional eating · Functional magnetic resonance imaging · fMRI · Neuroimaging · Alcohol misuse · Alcohol dependency · Substance misuse · Mindfulness

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Introduction

Arguably, the most important challenge in treating obesity on an individual level is not alleviating hunger or increasing satiation but finding a solution for the human association of food with positive affect and reward [1]. The neural networks controlling our experience of reward and goal-directed behaviour are potently and primarily stimulated by food and especially high-energy-density food [2–13]. Therefore, it is ironic that surgical, rather than psychological, interventions for obesity should prove to be the most effective tool that we have to treat obesity [14, 15]. On the other hand, if anatomical manipulations of the gut powerfully alter the hedonic evaluation of food, then the gut-brain axis may prove to be the most important target for the development of future treatments of obesity. There is increasing evidence to suggest that gastric bypass surgery affects food reward at a neural level. Functional magnetic resonance imaging (fMRI) studies have shown distinct patterns of brain activation to food pictures in humans after gastric bypass surgery, compared to before surgery [16, 17] and compared to unoperated obese patients or to gastric banding surgery patients [18]. Gastric bypass surgery also appears to distinctly alter striatal dopamine signalling compared to dieting [19]. Whilst on the face of this, bariatric surgery may therefore address perhaps the most important driver of overeating, there may also be consequences from losing the hedonic appeal of food that are not yet fully appreciated. Understanding the psychological and neurobiological underpinnings and consequences of bariatric surgical procedures will ensure the enduring success of any current or future intervention for obesity. In this paper, we aim to review the existing literature supporting the changes in food reward following gastric bypass surgery, explore whether there is evidence for subsequent reward deficiency in some patients and what the behavioural consequences or potential mediators may be.

Akin to drug or alcohol addiction, alterations in dopaminergic and opioid pathways involved in the expectancy, appraisal and receipt of food reward appear to be important in the development and maintenance of obesity. Several components of the reward system, including the striatal nucleus accumbens and caudate nucleus (key to dopaminergic reward conditioning, expectancy and motivation), amygdala (which governs emotional responses to rewarding stimuli), anterior insula (integrating gustatory and other sensory information) and orbitofrontal cortex (OFC) (reward value appraisal, cognitive control and attention), have been implicated [20–22].

Activation in these areas to food cues not only predicts food consumption [23] and choice [24, 25], and prospective weight gain [26, 27], but also may be altered in obesity [21], predict the success of weight loss strategies [28], and change with successful weight loss [29, 30]. Activation is also altered by specific eating behaviour psychopathology such as dietary restraint [31–33], binge eating disorder [34, 35] and hyperphagia in genetic obesity [36]. Top-down regulation of these brain regions by the dorsolateral pre-frontal cortex during the exercise of self-control appears to modulate responses to food [28, 37], and higher trait mindfulness is associated with less enduring reward system activation to food cues [38]. Interestingly, modulation of activation of these reward systems both at rest and in response to food stimuli by gut hormones (including the anorexigenic hormones PYY and GLP-1, secretion of which is exaggerated after gastric bypass surgery) has also been described [13, 39–41], particularly when administered in combinations to obtain additive effects [42]. Surgical treatments of obesity alter activation in these areas to food cues and different surgical techniques appear to alter activation differently [16, 18, 43]. The influence that learning processes have on establishing these changes remains to be determined.

In 2012, Ochner et al. reported a study of 14 female patients scanned 1 month before and 1 month after Roux-en-Y gastric bypass (RYGB) in which they found significant reductions in activation to food (high and low energy density) cues (visual and auditory) post-operatively in the dorsal striatum (lentiform nucleus and putamen) and middle and superior frontal gyrus. These reductions were significantly greater for the response to high-energy, compared to low-energy, food pictures and words [16]. Reductions in brain response for high- compared to low-energy food cues in the lentiform nucleus, caudate, middle and superior frontal gyri, ACC, thalamus and inferior parietal lobule significantly predicted reductions in desire to eat particularly high-energy foods.

In our cross-sectional study, we found that obese patients after RYGB had healthier gut-brain-hedonic responses to food than patients after gastric banding (BAND) surgery, despite the groups being similar in current body mass index and time since surgery [18]. Patients after RYGB had lower activation than patients after BAND in brain reward systems when evaluating food pictures, particularly to high-energy foods, including the OFC, amygdala, caudate, nucleus accumbens and hippocampus. This was associated with lower palatability of ice cream given after scanning compared to patients after BAND (and which correlated with reward system activation when evaluating high-energy foods). Patients after RYGB also had lower appeal ratings of high-energy foods and healthier eating behaviour, including less self-reported fat intake, compared to patients after BAND and/or BMI-matched unoperated controls. These differences were not explicable by differences in hunger or psychological traits between the surgical groups.

Weight loss after gastric BAND surgery can be predicted by increased activity when viewing food pictures, in the medial, middle, and superior frontal gyrus and posterior cingulate cortex (areas associated with cognitive control) [44].

Several animal and human studies have shown not only reduction in hunger but also changes in taste acuity and a shift towards healthy food choices after gastric bypass surgery [45], although the human literature is limited by most studies relying on verbal report [46]. Post-ingestive symptoms (dumping symptoms) after sweet and fatty foods may contribute to this change in hedonic value of certain foods, by conditioned aversion or avoidance. Several animal studies have found that rather than total avoidance of sweet and fatty foods, there continues to be multiple approaches towards these foods after gastric bypass surgery, but a decreased overall intake [47], implying that they may still enjoy these foods but learn to consume small quantities to avoid discomfort, and hence, current observation favours the theory of conditioned avoidance rather than aversion. Food addiction, arguably the behavioural phenotype most closely correlated to alcohol or drug addiction, and therefore the group most likely to benefit from an intervention reducing reward from food, reduces after gastric bypass surgery as measured by the Food Addiction Scale [48].

Post-prandial, and sometime also fasting, anorexigenic gut hormones and bile acids are elevated after gastric bypass surgery and have the potential to influence the taste system and food hedonics. Data from our studies show that acute reversal of the exaggerated post-prandial plasma PYY and GLP-1 concentrations in RYGB patients by administration of the somatostatin analogue octreotide increases the hedonic appeal and reward system activation to food cues suggesting a potential mechanism behind the reduced food reward after gastric bypass surgery [49]. Similarly, the additive role of gut hormone or agonist administration to further increase the effect of gastric bypass surgery (or indeed another bariatric operation such as BAND), as suggested by animal studies [50], warrants further investigation in humans and may have particular relevance for patients where weight regain occurs after RYGB.

It has been hypothesized that a reduction in reward from food after gastric bypass surgery may create a reward deficiency associated with heightened hedonic responses to other emotion-regulating substances, such as alcohol, referred to as 'switching addiction'. There is strong evidence to suggest that alcohol addiction may be a significant potential complication after gastric bypass surgery in some patients [51]. King's and other studies have shown increased alcohol and other drug misuse and dependency in obese bariatric surgery patients [51, 52], particularly after gastric bypass surgery [53].

A retrospective study of patients presenting to the Mayo Clinic found that around 5 % of patients between 30 and 60 years of age presenting for treatment of alcohol dependency had undergone bariatric surgery in the past, mostly gastric bypass surgery [54]. Their histories reflected that 39 % had a past history of alcohol misuse, but a surprising 17 % were teetotalers before surgery, suggesting an increased vulnerability initiated by the surgery. There was an increase in alcohol intake around 17 months after surgery, progressing on to dependency levels by year 3, and severe enough to warrant inpatient treatment by year 5. Men progressed to alcohol dependency faster than women. In another study of 141 gastric bypass surgery patients at least 2 years post-surgery, 14 % fulfilled criteria for substance misuse disorder (tobacco, sedative, alcohol, cannabis and cocaine in descending relative frequency of use) [55]. Substance misuse was associated with poor weight loss and a family history of substance misuse as well as pre-operative food addiction, maladaptive eating behaviour, and heightened responsiveness to environmental food cues. In their sample, 70 % of those who met post-surgical probable substance misuse criteria reported developing this problem de novo following their surgery.

Proposed mechanisms for the increased rate of alcohol dependency after gastric bypass surgery include the altered metabolism of alcohol, which means that intoxication is achieved more easily and quickly than before surgery [56]. However, the loss of food as a rewarding substance thereby potentially sensitizing brain reward systems to other addictive substances may also contribute and fits with the finding of a higher risk amongst patients who have previous food addiction [57]. These findings may have particular relevance not only to obese patients undergoing RYGB who have a history of drug or alcohol addiction or misuse but also potentially for those who use the rewarding aspects of food as a way to manage stress, anxiety, depression or other difficult emotions.

Whether other impulsive and addictive behaviours such as gambling, sexual promiscuity and overspending also increase after gastric bypass surgery has not been examined.

Psychological problems including depression and alcohol use after gastric bypass surgery are associated with weight regain [58]. Eating in response to emotional distress after surgery has also been linked to poor outcomes after surgery, and its presence pre-operatively may predict poor outcomes [59, 60].

Furthermore, perhaps too much value is placed on weight loss as an outcome. Whereas weight loss is important for the improvement of physical health, and in general, mental health and well-being are improved following weight loss after bariatric surgery, a minority of patients continue to report no psychological benefit from surgery or a return of pre-morbid depression or new emergence of new psychological difficulties [61]. Increasingly, patients report psychological difficulties after bariatric surgery, which are not necessarily captured by traditional means of testing such as the Beck Depression Inventory. Nonetheless, these impact significantly on health expenditure, quality of life and patients' experience of bariatric surgery. For instance, post-operative development of maladaptive eating (linked to weight regain), psychological distress (depression, anxiety and guilt), and somatization of psychological distress (leading to increased hospital or medical-attention-seeking behaviour for post-prandial pain, nausea, vomiting and dehydration) have been linked to the presence of specific personality traits and styles of coping [62].

There is also the suggestion from several cross-sectional studies that gastric bypass surgery may be associated with increased suicide risk [63]. The Utah Mortality study comparing approximately 9000 patients who had undergone gastric bypass surgery compared to BMI-matched unoperated obese controls found an increased risk of suicide and accidental death [64, 65]. Another study found a rate of 13.7 per 10,000 (men) and 5.2 per 10,000 (women) of completed suicides in over 16,000 bariatric surgery patients, compared to 2.4/10,000 (men) and 0.7/10,000 (women) age and sex-matched suicide rates in the US population [66]. Although it could be argued that bariatric surgery patients have a higher psychiatric co-morbidity to begin with than similarly obese patients not seeking surgery, nonetheless, this finding does call into question whether psychological health is truly restored after gastric bypass surgery in all patients or whether there are more subtle effects from the loss of food from a hedonic point of view that are being missed.

For instance, if food is used to dampen negative affect, removal of the positive affective reward from food may in fact make certain individuals more vulnerable to psychological distress, depression and even suicide. Pre-operative assessment and preparation should therefore arguably include the teaching of strategies to help improve emotional regulation particularly in those found to have a strong hedonic attachment to food. More emphasis is also needed on proactive strategies in postsurgical patients rather than a reactive approach that seeks to address the problem only once it has occurred. This may be particularly relevant in morbidly obese people where access to and the ability to use alternative coping strategies (e.g. such as exercise) may have been and may remain diminished by poor mobility, social isolation, depression and low self-esteem. If on the other hand, the reduction of the hedonic appeal of food is generalized, then this may have implications for pharmacological targets for treatment of other forms of addiction.

The psychological preparation and follow-up of post-bariatric surgery patients need further study [67], as we move away from assessment and screening towards a more holistic understanding of how psychological factors may impact on patients' ability to use surgical treatments and aim towards targeted and personalized interventions pre- and post-surgery [58, 68]. Studies aimed at improving psychological and dietary preparedness have shown limited effects [69–71], but the more lasting effects of bariatric surgery on psychological well-being are woefully understudied and hampered by an overmedicalized approach to obesity.

Physical exercise is a positive predictor of outcome after bariatric surgery [72, 73]. Mindfulness has also emerged as the equivalent of regular physical exercise for maintaining mental well-being [74] and has been shown to improve health outcomes in a variety of settings [75], most consistently for the prevention of relapse from depression [76], while also improving maladaptive eating behaviours [77, 78]. Mindfulness is best defined as the learned ability to focus mental attention in a sustained manner in a non-judgmental way so as to increase self-awareness. Mindfulness practice cultivates acceptance and tolerance of distress without having to find a solution. Put otherwise, it mediates the need to immediately resolve distress and improve affect with a substance such as food. As such, it is frequently incorporated into programmes aimed at the management of disorders where tolerance of distress is low, such as emotionally unstable personality disorder [79]. Practicing mindfulness increases work satisfaction, reduces adverse experience of stress, increases creativity and personal success, improves relationships and enhances emotional intelligence [80].

Mindfulness training within an 8-week course has been shown to mediate the reward pathways and provide a way of exercising top-down control over the salience of monetary incentives by altering the value signals in ventromedial prefrontal cortex (vmPFC) coupled with the bilateral posterior insula [81]. The collective results of studies by Kirk et al. suggest that mindfulness training is capable of lowering activation in the caudate nucleus and elevating bilateral posterior insula activation during reward anticipation. Mindfulness also reduces activations in the vmPFC during reward receipt and is able to modulate amygdala responses to threatening stimuli [81–83]. Overall, it appears that mindfulness integrates interoceptive input from the insula in the context of value computations of both primary and secondary rewards and thus offers a new approach to the problem of reward deficit. Testing the efficacy of mindfulness in patients after gastric bypass surgery appears feasible, especially now that this patient group has been identified as vulnerable.

Conclusion

In summary, the idea that surgery on the gut may change food reward responses in the brain is supported by evidence from behavioural and neuroimaging studies. Identification of the alterations in the gut-brain axis and hence food hedonic responses as a result of altered gut anatomy/physiology provides a novel explanation for the more favourable long-term weight loss seen after gastric bypass surgery compared to other surgical and dietary interventions. Interrogation of the differences in these underlying mechanistic pathways between gastric bypass and gastric banding surgery is therefore an important step towards the improved use of current treatments and the development of new treatments, targeting the gut-brain reward systems.

The inference that there exists a void for emotional sustenance and reward after gastric bypass surgery where food previously functioned is suggested by the evidence of increased risk of addiction to alcohol and other substances and other maladaptive behaviours such as somatic expression of psychological distress and suicide. Whilst the positive impact of bariatric surgery on both physical and psychological outcomes for many patients is clearly evident, a subset of patients appears to be detrimentally affected by this loss of reward from food and by a lack of alternative strategies for managing difficult feelings after surgery. Mindfulness training has emerged as a potential tool in reducing the need for immediate reward that underpins much of eating behaviour and may also underpin the emergence of other maladaptive behaviours after gastric bypass surgery. The positive top-down influence on neuronal reward systems of mindfulness has been demonstrated by fMRI studies and offers encouraging empirical support for it to be formally tested in this setting. Further research is needed to help identify patients who may be more vulnerable after gastric bypass and which forms of support may be most beneficial in preparing pre-operative patients and supporting post-operative patients.

Compliance with Ethics Guidelines

Conflict of Interest Samantha Scholtz, Anthony P. Goldstone, and Carel W. le Roux declare that they have no conflict of interest.

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